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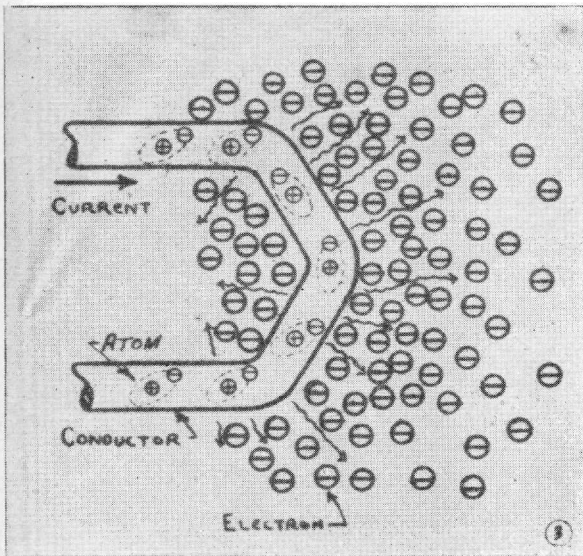
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Principles of Electron Tubes

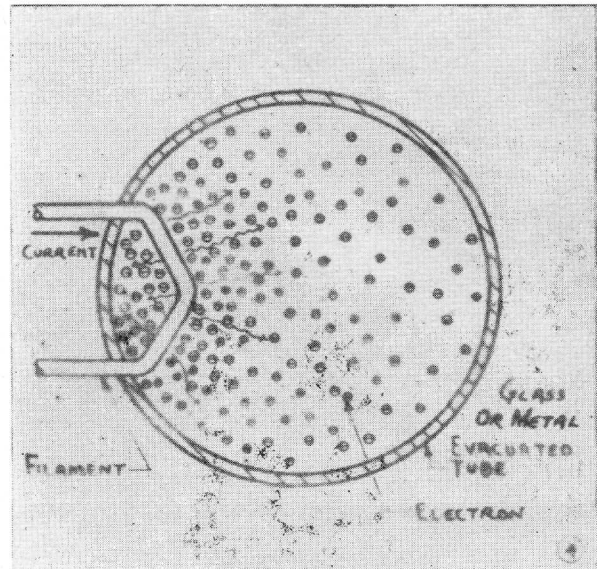
By YVONNE LAMOREAUX, E.E.I.

TO fulfill many of industry's special needs at present, many diverse applications of electron tubes have suddenly become prominent. The elements of the theory of these tubes herein presented are easily understood, assuming only the basic fact that electrons do exist and that they flow in a stream of current. This stream of electrons may be readily controlled by the addition of other elements into the envelope. The addition of these elements results in greatly different characteristics which enable the tube to be used for many other purposes. In the following pages the sequence of the tubes will be demonstrated, and the effects of the introduction of new elements into the envelope will be shown.



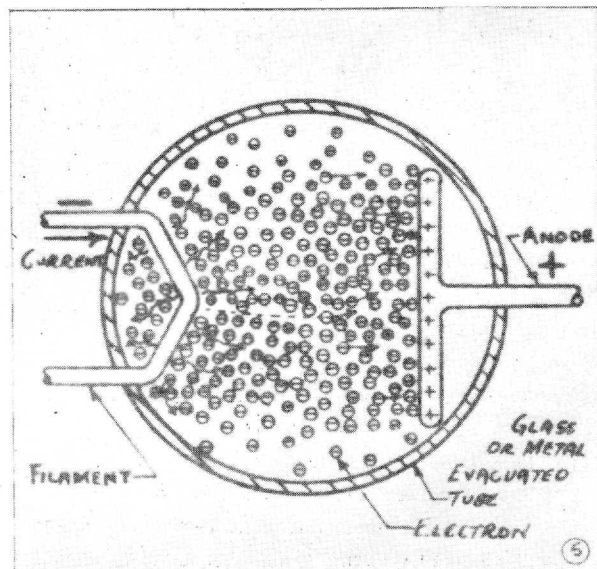
WHEN an electric current flows through a resistance wire the same effect is produced as when a solid is heated. When the wire temperature is raised to approximately 2400 degrees K, electrons are emitted. Since electron emission depends only on temperature, the same number of electrons will be emitted by passing alternating or direct current through the wire. The heat in watts generated in the conductor equals the current in amperes squared times its resistance in ohms.

To minimize the oxidation of the conductor at the high temperatures required for electron emission the resistance wire is placed in an



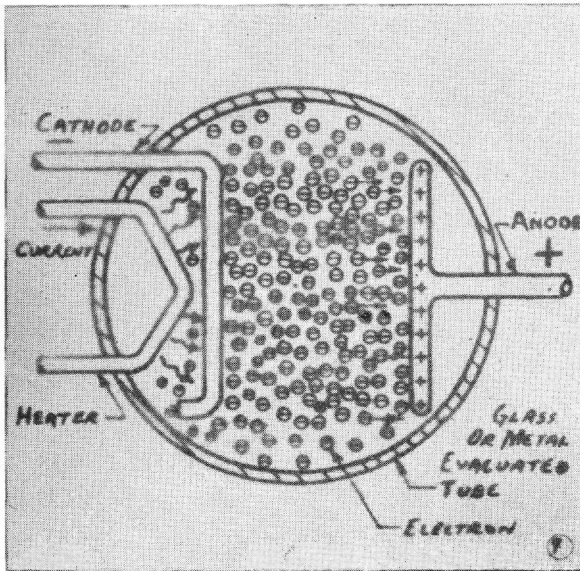
evacuated glass shell. Although the tube emits electrons, it is nothing more than the incandescent lamp and is not classified as an electronic device. The reason for this is that the electron emission cannot be utilized, and its main use is as a source of heat or light.

This tube is a vacuum diode. Edison first discovered that a current of electricity would flow between two filaments inside the evacuated bulb. This occurred, however, only when the anode



potential was made positive. A negatively charged electrode repelled electrons. In order to understand and apply electron tubes it is necessary to think of electron flow as from negative to positive points of potential. Because of this electron flow from negative to positive the diode tube makes an excellent rectifier.

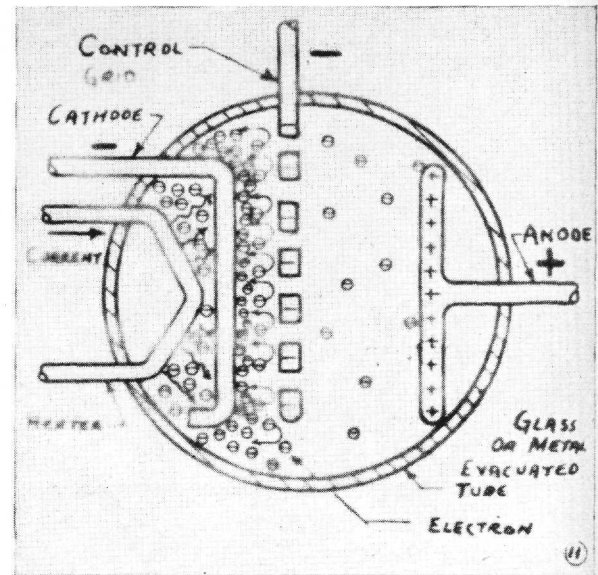
It has been found that such materials as barium, calcium, strontium, and thorium oxides



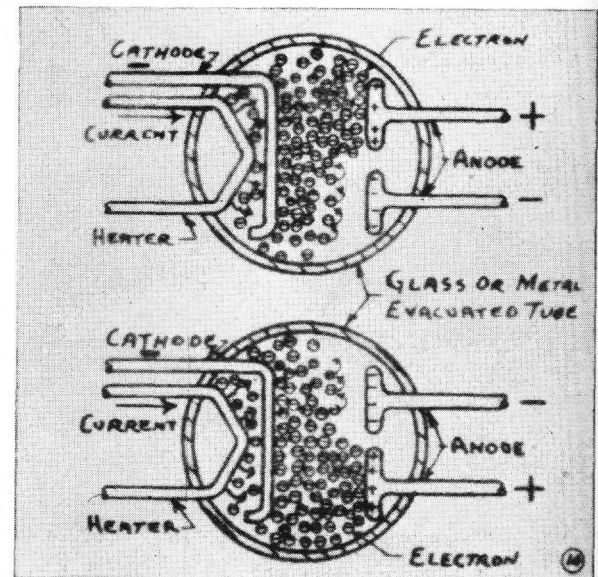
will emit electrons at a much lower temperature than tungsten. Since these substances cannot be formed into a filament directly, a thin coating of these substances is applied to a high resistance filament. This coating will increase the electron emission from the filament. However, since applying these coatings to a filament is quite expensive, they are usually applied to a metallic surface known as the cathode. The cathode is placed near the coated filament which is known as the heater. The heater does not emit electrons itself. It raises the temperature of the cathode to efficient temperature for electron emission. This tube is better, in many cases, than the filament type, since it requires less heat for the same amount of electron emission.

DeForest, in 1907, placed a metallic grid between the cathode and anode of the two-element tube. When he made the grid potential negative it was found that the anode current would decrease in value below what it was when the grid potential was zero. This corresponds to an increase in space charge, which is defined as a saturation effect when the number of electrons flowing from the cathode to the anode cannot increase regardless of temperature increase.

When DeForest made the grid potential positive it was found that it assisted the field of the anode. Because the grid is nearer the cathode than the anode a change in grid potential will



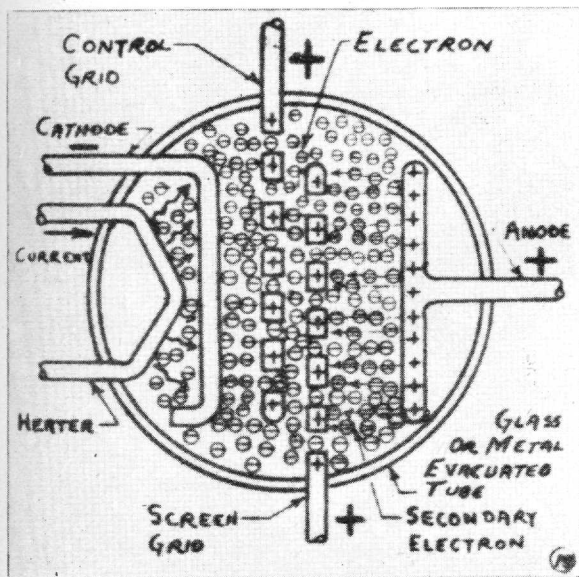
produce a greater effect on the electron flow than the same change in anode potential. This type of tube is a triode. Since the grid can control the anode current flow by a change in grid potential, it acts like a regulating valve. This tube may also be used as a variable resistor since the grid potential controls the anode current just as a resistor is manually operated to vary the current in a circuit.



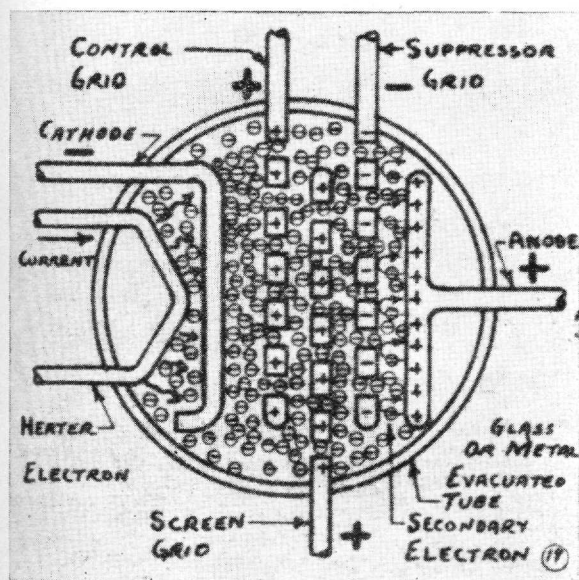
This tube is a three element full wave rectifier tube. Here, in place of a grid, a second anode is used. The tube is really the equivalent of two diode tubes built into one unit. Since only one heater is used for both anode circuits it is economical for use in low power d.c. units. A positively charged anode attracts the electrons while the other repels them, preventing current flow to the external circuit. As is shown by the illustration, the plate charges may be reversed.

When a tube is operated at high frequencies the capacitance between the grid and cathode, of

very little consequence in low frequency circuits, is detrimental to high frequency operation. If the tube is used as an amplifier at high frequencies the output will be distorted. Eventually the feedback of energy from anode to grid will cause oscillation, lessening greatly the tube's value as an amplifier. With the addition of a

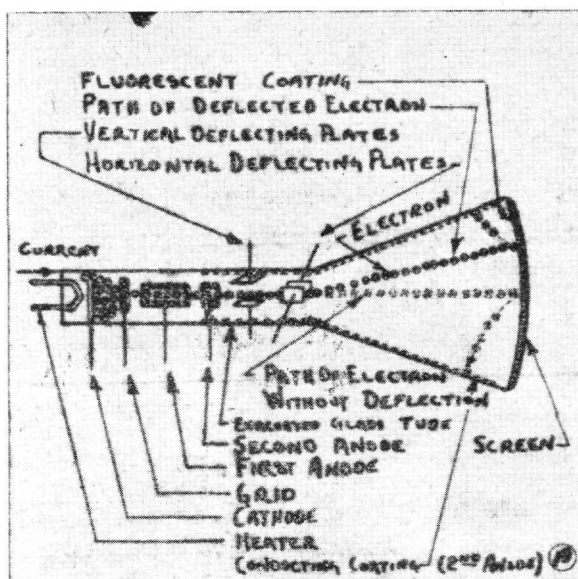


second grid, or screen, the capacitance will be greatly reduced. The screen must be maintained at ground potential in order to act as an effective screen. Because the tube has four elements it is known as a tetrode.



With the addition of a third grid the tube becomes a suppressor grid tube, or a pentode. The suppressor grid is usually operated at the same potential as the cathode. When secondary electrons are emitted from the anode they are repelled by the negatively charged grid and returned to the anode, eliminating the undesirable negative resistance characteristic of the tetrode.

Both the screen grid and the suppressor grid are made of fine wire spaced relatively far apart. This permits most of the electrons to go through on their way from cathode to anode.



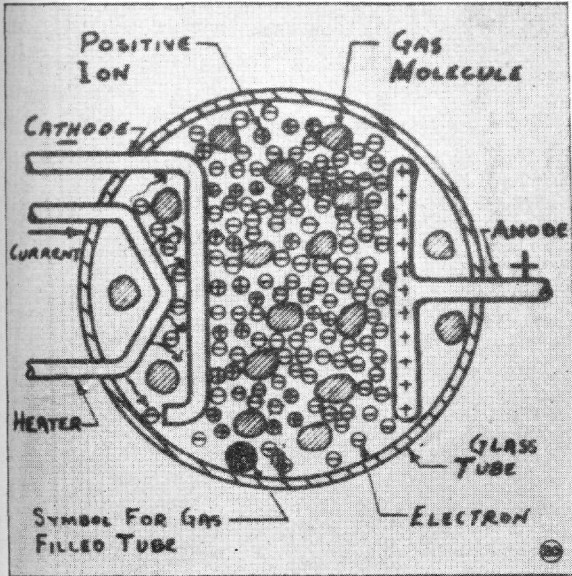
The cathode ray tube is used in studying periodic and transient wave motions. In the tube, the grid controls the density of the flow of electrons from cathode to anode and the intensity of the luminous spot or wave shape on the screen. The first and second anodes act together to give the beam a sharp focus on the screen. The second anode, since it is operated at a high potential in respect to the cathode, determines the final electron velocity. The end of the tube has a fluorescent coating which glows for a period of time depending on the velocity of impact and concentration of the beam. The electron stream may be deflected either electrostatically or magnetically. The tube may be used for observing hysteresis loops, circuit breaker operating characteristics, modulation, and for television reception.

In a high vacuum tube, even a minute amount of gas will produce a luminous glow and the tube will be unsatisfactory for use as an electronic device. However, gases inserted into the tube at the proper pressure will produce reactions greatly different than those of a vacuum tube. In a gaseous tube the cathode emits electrons in a manner similar to the cathode emission in a vacuum tube. The tube is completely filled with gas. Since a gas molecule moves only 1/1600th as fast as an electron, the molecules are often struck by electrons moving from the cathode. These electrons strike the molecules with such great force that more electrons are knocked loose from the molecule. These electrons move, too, to the anode, setting free other electrons. As is seen by the gaseous tube above, more electrons reach

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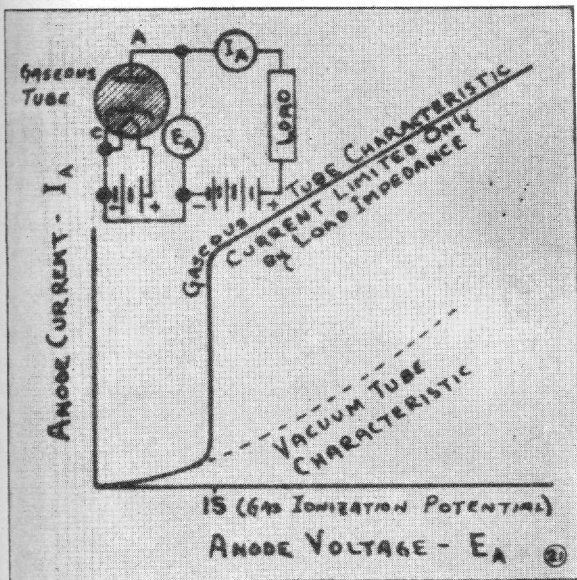
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the anode than leave the cathode when the tube is first operated.

Here the characteristics of the vacuum tube and the gaseous tube are compared. The main



differences are: (a) a vacuum tube has a large voltage drop; (b) the vacuum tube has a high effective resistance from cathode to anode, while that of the gaseous tube is low; (c) a vacuum tube requires a high anode voltage to obtain a large anode current, but the gaseous tube requires practically no change in anode voltage; and (d) the vacuum tube has an energy transfer of medium efficiency while the gaseous tube has a very high efficiency.

The addition of a control grid widens the application of the gaseous tube. The grid in the gaseous tube performs a different operation than

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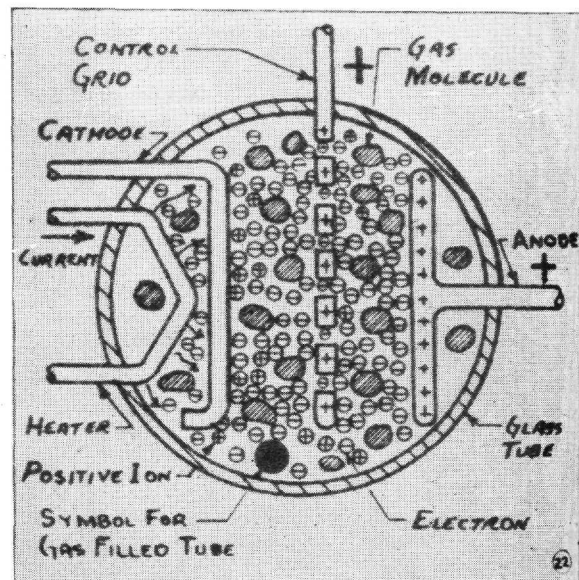
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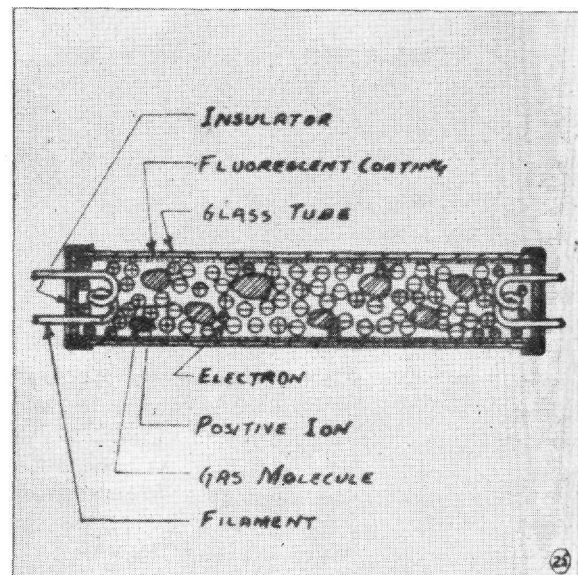
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the grid in the vacuum tube. It has no control over the magnitude of the current after the current flow has started. It merely serves as a trigger to start the current flow. This tube is used in many industrial control applications as a contactor or relay, and is commercially known as a thyatron.



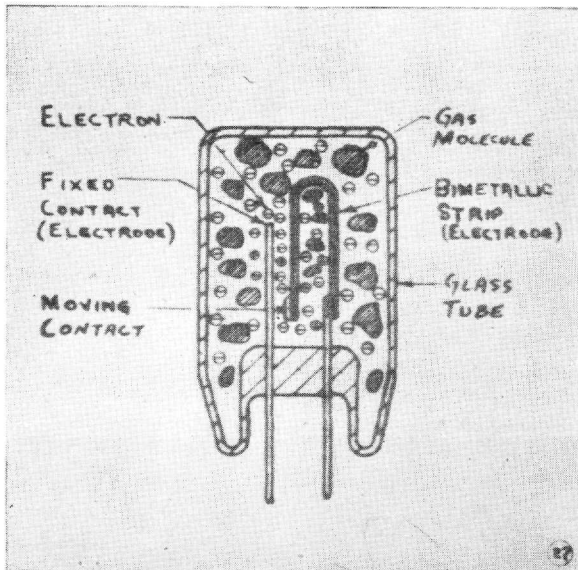
The fluorescent tube is shown here. When the filaments at each end of the tube are heated, mercury vapor is formed. After a suitable heating period, a high voltage is impressed between the filaments for a short time. The voltage causes the mercury vapor in the tube to ionize and glow. Once the tube has started to glow, it may be

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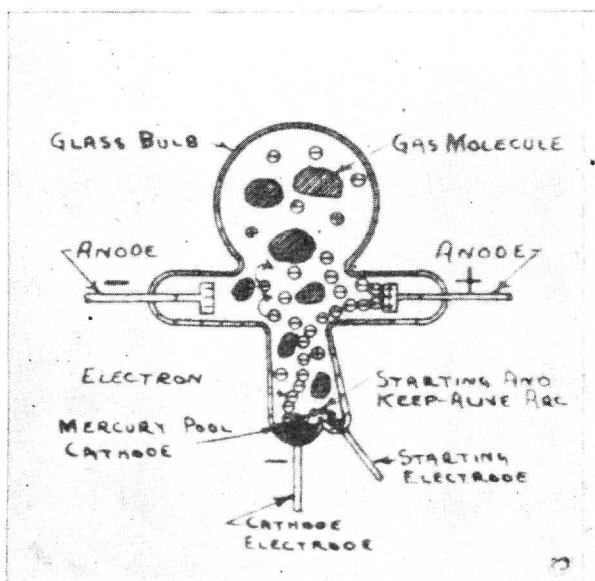
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kept continuous by normal voltage. The extremely brilliant and efficient light comes from the fluorescent coating on the inside of the tube, which gives forth a bright glow when subjected to the ultra-violet rays of the mercury vapor glow discharge.

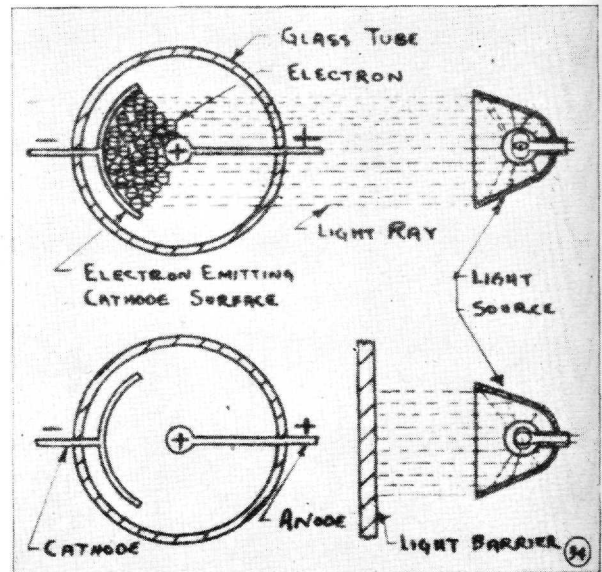


This device is known as a fluorescent lamp glow-tube starter switch. One of the electrodes of the tube is made of bimetal and will deflect toward the other electrode when heated. The glow discharge current heats the bimetallic electrode. Used as a starter switch for fluorescent lamps it provides the necessary time delay for the lamp filaments to heat. This device is also used as a timing element in a motor starter.



In order to start the arc of current from the mercury pool cathode to the anode, the mercury arc rectifier tube must be tipped until contact

is made between the two pools. When the tube is returned to its normal position an arc is drawn consisting of electrons and ions which are diffused through the tube. Current is conducted from the cathode spot to the anodes in a manner similar to the conducting of electrons from cathode to anode in a vacuum or gaseous tube. After the arc has been started, a "keep-alive" arc is used to maintain the arc. Additional electrons are obtained from the collision of the electrons with the gas molecules. This tube is called a mercury arc rectifier.



Utilizing the ability of some oxides to emit electrons when subjected to light rays, the phototube is a valuable electronic device. The typical phototube has two electrodes, one a semicircular cathode and the other, the anode, is a straight-wire electrode, placed in the tube so its axis coincides with that of the cathode. The cathode consists of a silver base metal coated with some light-sensitive material such as calcium oxide. Light energy is necessary for electron emission. The number of electrons emitted is directly proportional to the intensity of the light. A minute current is created by the movement of electrons to the anode, but it is so small that an amplifier is used to amplify the current so it will be of practical use. The tube may be either a vacuum or gaseous tube. Gaseous tubes, it has been found, provide a greater output per unit of light than the vacuum tubes.

It will be seen that the importance of electronics is growing and will be of great value in industry at peace as it is now in industry at war. If electronic engineers and physicists continue to use their untiring efforts toward the invention and development of applications of the electronic tubes, we shall see many wondrous things at the conclusion of the war.